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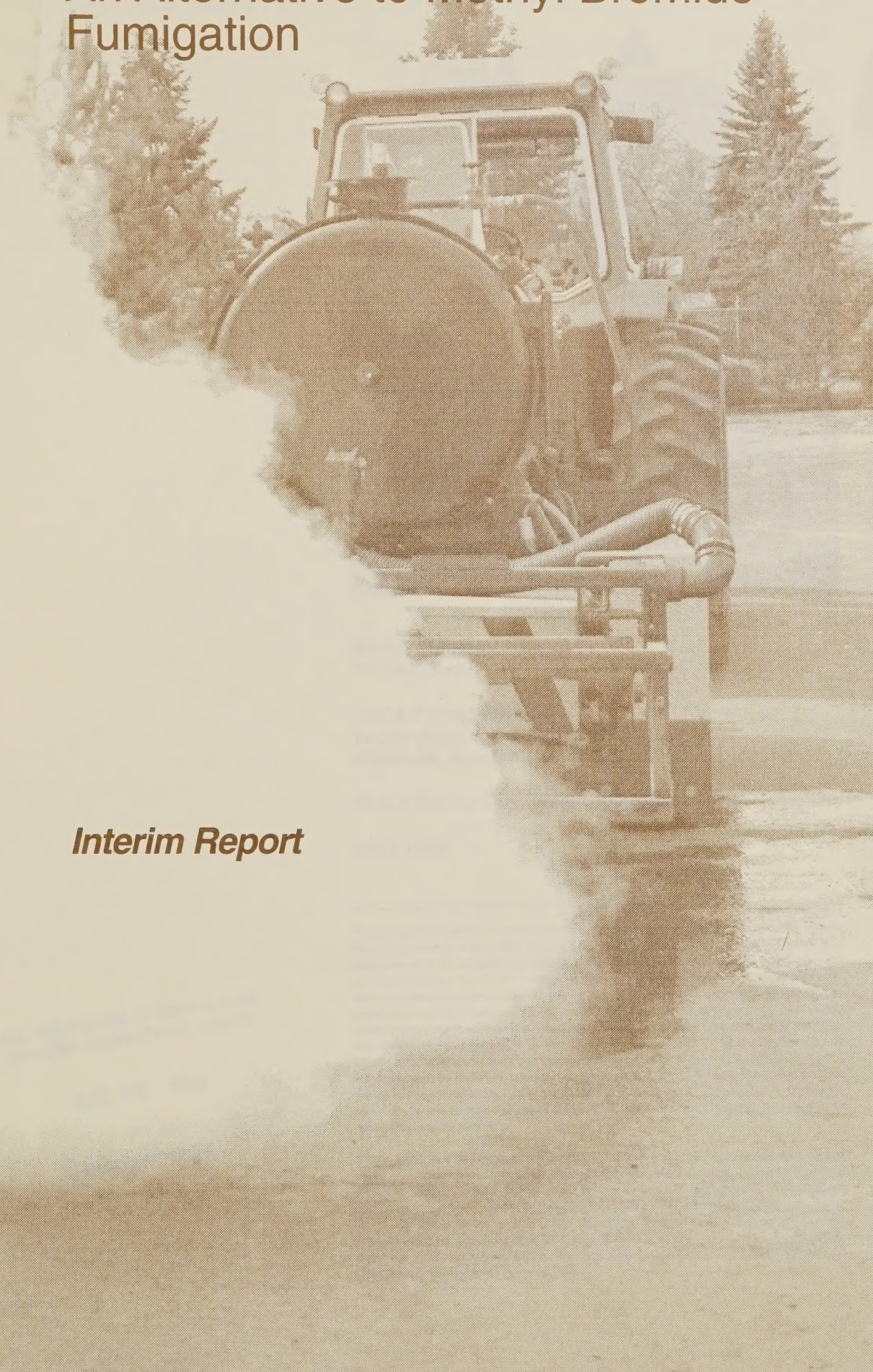
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Steam Treating Soils

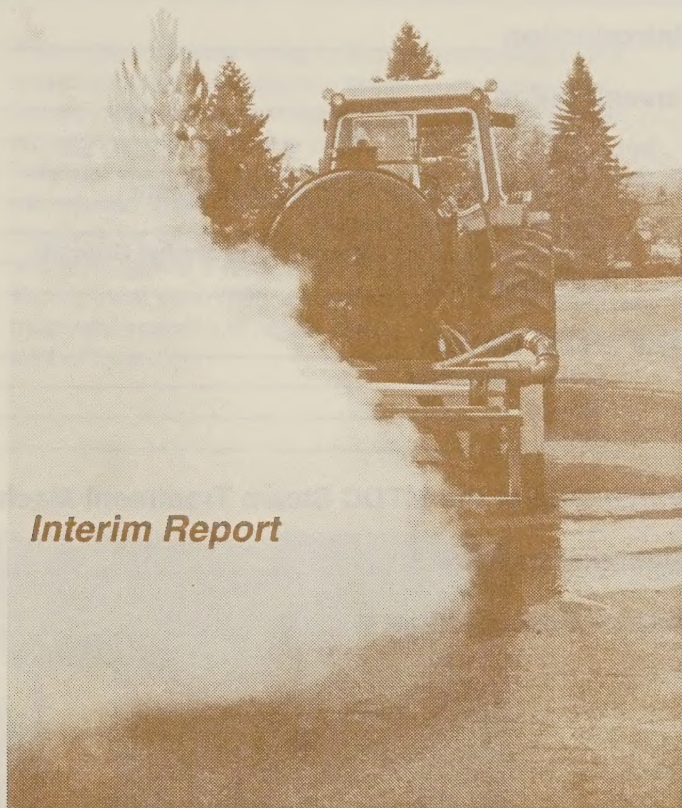
An Alternative to Methyl Bromide Fumigation

Interim Report



Steam Treating Soils

An Alternative to Methyl Bromide Fumigation



Interim Report

Richard Karsky
Project Leader

**USDA Forest Service
Technology & Development Program
Missoula, Montana**

4E42E35—Nursery Soil Fumigation

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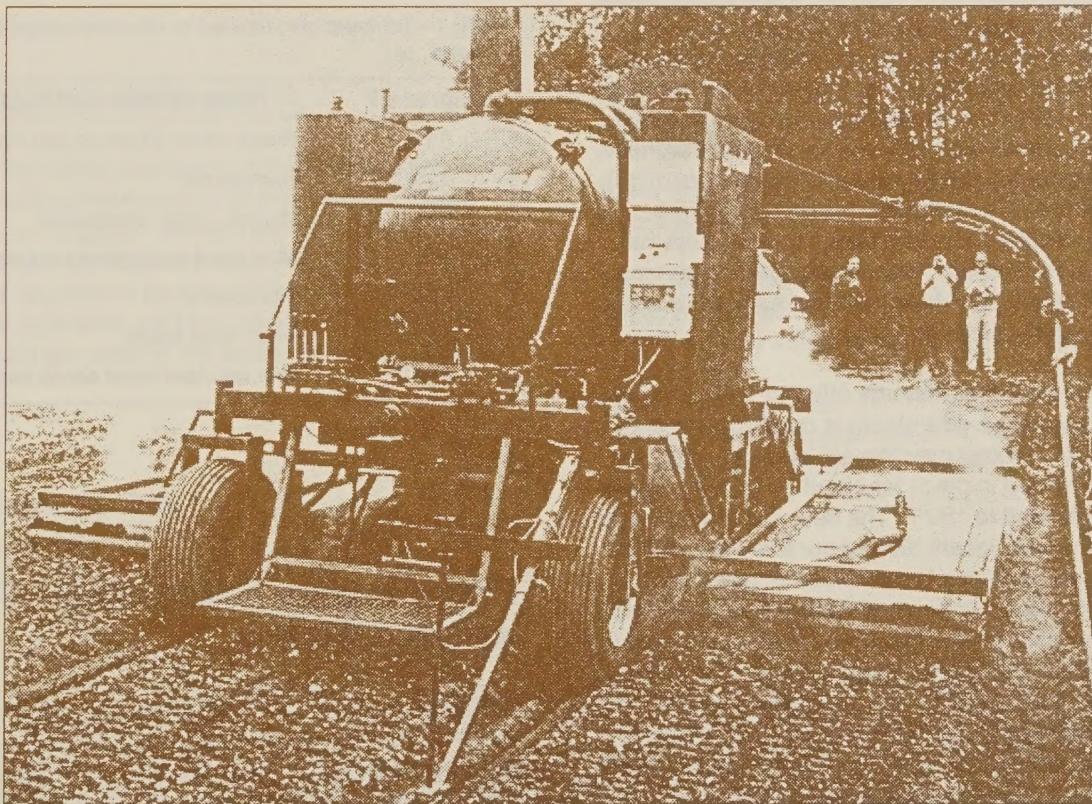
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Introduction

The growth of young trees is affected by pathogens in the soil at tree nurseries. Certain cultural practices, such as crop rotation, have been used to reduce the level of pathogens in the seedling beds. Chemicals have commonly been used to sterilize the beds before sowing seeds. If these practices are followed, the chances of a successful seedling crop are increased. Fewer treatments are needed to correct diseases that affect the seedlings. The two main chemicals used to sterilize the seedling beds are Basimide and methyl bromide. Methyl bromide, the fumigant of choice, has been found to be environmentally harmful and will be banned from use by the Environmental Protection Agency in the year 2001. Methyl bromide was very effective at controlling microorganisms and killing weed seeds.

This project involves trying to find an economically and environmentally acceptable method of sterilizing soils. Steam has been used in Europe to prepare the soil for nursery operations. In the 1950's, steam rakes were used successfully in the United States to treat soils. They were abandoned when methyl bromide came on the scene because the fumigant was faster, easier to use, and was effective against a wide range of organisms and weeds. During fiscal year 1995, the center built a prototype steam treatment machine to obtain data on its effectiveness and cost of operation.



Investigation

The Center's investigation of alternative methods of controlling soil pathogens revealed that several people have used steam and hot water to control soil pathogens. A product search revealed that equipment used for steam or hot water treatment of soils were either prototype machines or were not readily available. Egedal, a Danish manufacturer, makes a machine that will steam-treat nursery beds, but it is very costly.

Yoder Brothers Nursery

Andrew Bishop, Ph.D., is Plant Protection Manager for Yoder Brothers, Inc., in Alva, FL. He discussed their trials using steam to sterilize nursery soils. Yoder Brothers grows and plants chrysanthemum cuttings to be used by green-houses 52 weeks a year. They have started a pilot project in which they are evaluating steam as an alternative to methyl bromide. They were looking for an alternative to fumigants that might also be removed from the approved use list by the EPA. Their preliminary results show that steam treating soils has eliminated Fusarium, Pythium, root rot, and other diseases. The preliminary results also show that the treatment is cost-competitive with methyl bromide.

Their machine consists of an "energy efficient" (97%) steam boiler fired with diesel fuel. The steam is conducted to an aluminum box that is placed over the soil surface. After the enclosure has remained in place for about 20 min, the upper 10 in of the soil is heated to 180°F. The device is lifted, moved forward, placed on an adjacent area of nursery bed, and the process is repeated. Because Yoder Brothers grows and plants year-round, the slow speed of this process is of minor concern. The device is operated by one person, compared to the three or four people who are needed to apply the methyl bromide. This offsets some of the disadvantages of slow operation. A winch moves the machine down the nursery bed and pneumatic actuators raise and lower the steam box. Zifort, Inc., of West Germany manufactures machines similar to the device built by Yoder Brothers. No information is available on Zifort's machine.

John Bartok

John Bartok, Jr., an extension engineer at the University of Connecticut, works with the nursery industry in Connecticut. During a presentation at the Western Forest Nursery Association conference in Moscow, ID, he described steam sterilization of soils. He said:

The lethal temperatures necessary to eradicate soil pests are shown in Table 1. Good results can be obtained with a temperature of 160 to 180°F, for 30 minutes. A probe-type thermometer works well for measuring temperature.

The amount of heat needed to raise the temperature of a given volume of growing media depends on the components, its moisture content and the difference between the cold soil temperature and desired treatment temperature. The heat flow rate needed per minute depends on how quickly the mix must be brought up to the desired treatment temperature. For most applications, 30 minutes heating time and 30 minutes contact time is considered the norm

Table 1—Temperature required to kill certain organisms (from John Bartok, Jr.).

Degrees F	Pests or Weeds Affected
115	Water molds (Pythium and Phytophthora)
120	Nematodes
135	Worms, slugs, centipedes
140	Most plant pathogenic bacteria
160	Soil insects
180	Most weed seeds
215	Few resistant weed seeds and plant viruses

Free-Flowing Steam and Aerated Steam

Of the two methods used for steam soil treatment, free-flowing steam is the least expensive, considering equipment costs. Aerated steam is the most effective. Free-flowing steam is injected directly into the ground as it is generated. The temperature of the steam would be about 210 to 230°F. Aerated steam is steam vapor mixed with air to obtain a specific vapor temperature before being injected into the ground.

Steam leaves the boiler under slight pressure (5 to 15 psi). As soon as steam is released into the soil, its pressure drops to atmospheric pressure. The steam gives up its heat and its pressure drops. At this point it is considered free flowing. As long as the injection rate does not exceed the rate that steam can condense (about 18 lb/hr/ft² of exposed medium surface), blowout does not occur (blowout is when soil is blown or displaced enough in an area that steam readily escapes). The soil should be well mixed, having uniform

moisture, and the seed bed should be level. Disadvantages of free-flowing steam include killing too much of the microflora because of the high temperature, increase in total soluble salts, and changes to the soil structure.

In the aerated steam method, steam from a boiler is combined with air from a high-pressure blower to create a 140- to 180-° F mixture that is forced through the growing media. Advantages include about a 40% reduction in the quantity of steam needed and a more rapid, even heating of the soil.

Cold soil or wet soil will require more Btu's of heat and a longer treatment time. Frozen soils are difficult to treat with steam heat. A large amount of heat is required to change water from the solid to the liquid form.

Montana State University

Montana State University students have presented two machine proposals using steam as a soil sterilizer. These proposals were put together during their senior design class. From their proposals and calculations, using steam to replace methyl bromide appears to be economical and technically feasible, but the operation will be quite slow. The Center's design was based on some of the results of these proposals.

Microwaves as an Alternative to Methyl Bromide

Jim McDonald, Ph.D., Professor of Plant Pathology at the University of California-Davis, has conducted some research using conventional microwaves (20,450 MHz) as an alternative to methyl bromide. He is just getting started on some experiments and is working with personnel from the Crocker Nuclear Lab on the university campus, using conventional microwaves. He is trying to get a grant to work with the Lawrence Livermore Lab, using their microwave equipment to determine if different frequencies would inhibit pathogens without harming desirable microorganisms. The microwave generator and monitoring device each would cost about \$250,000. The Lawrence Livermore Lab has both devices. McDonald thought a device that lifted the soil and treated the top few inches would be more efficient than

one that just passed over the soil and had to heat the whole soil mass. The parameters used as a guide for temperatures soil treatment requires are obtained from Ken Baker's (UC Manual No.27) 1950's work on sterilizing soil for containerized nursery stock.

Canadian Work

Center Investigators met with Sid Lucas from the Ministry of Natural Resources, Canada, in the fall of 1995. He had done some work at the G. Howard Ferguson Forest Station, at Kempville, Ontario. They have used the Egedal Steam Machine and the Aqua Heat hot water machine in their nursery and have ongoing tests. Their nurseries plant in rows at seed densities of 400 seeds per m, (122 seeds per ft, or 10 seeds per in). They are working with Bill Carey and David South of Auburn University.

Some of the findings in studies at the G. Howard Ferguson Forest Station were:

Aqua Heat (Figure 1):

- Uses a lot of water.
- Field is soupy after treatment; you can't drive back over the treated area.
- Does control weeds.
- Obtained soil temperatures of 70°C or 158°F.
- Treats soil to a depth of 10 inches.



Figure 1—Aqua Heat hot water machine applying hot water with rotovator.

Egedal (Figure 2):

- Takes about 30 hrs to treat 1 acre.
- Steam penetrates just 3 to 5 inches in the soil.
- Beds have to be formed before using machine (needed to form seal).
- The topsoil temperatures are higher than 158°F, providing good weed control.
- Development of the (first prototype) machine began in about 1992.

We discussed the Center's steam generator design and the results we might expect with Lucas. Because the steam is injected below the surface, the topsoil may not reach temperatures high enough to kill weed seeds.

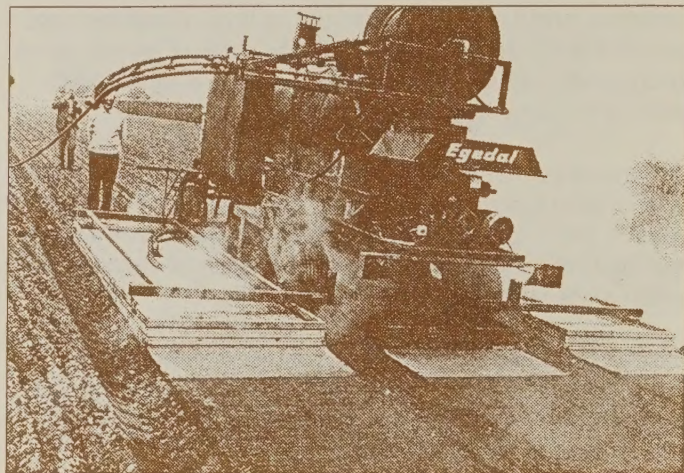


Figure 2—Egedal steam treatment machine treating three nursery beds.

The MTDC Design

The Center's design (Figure 3) consists of a portable steam generator that is pulled through the field by a tractor at very slow speeds. The tractor will have to be equipped with a creeper gear transmission to travel this slowly. The steam from the generator and air from a blower is mixed and injected into the ground through a blade. This blade is attached to the back of the steam generator (Figure 4) and can be hydraulically raised and lowered. The bottom of the blade is hollow and has a series of slots for the steam to pass through. A tarp is placed over the soil and above the blade to trap and retain the heated vapor and steam. The tarp is about 10 ft long, long enough to trap the heat and maintain the desired temperature for at least 20 min. A temperature probe was built and placed immediately behind the blade (Figure 5) to record the temperature at three different levels below the surface.



Figure 3—The MTDC steam treatment machine.



Figure 4—Rear of MTDC steam treatment machine, showing the injector blade.

Steam Generator

The steam generator used for this machine was a portable unit built for us by Saskatoon Boiler Manufacturing Co., Inc., Saskatoon, Saskatchewan. It is a 1.2 million Btu generator that is diesel powered. It carries its own water and fuel. The generator is well insulated, automated, and easy to operate. It will be pulled by a tractor equipped with a special reduction transmission during the initial testing.



Figure 5—Temperature probe showing the three thermocouples at different levels.

Blower

The aerator blower that was designed for use with the steam generator was not received by the contractor. This unit was to use a positive displacement blower capable of delivering 400 ft³/min at a static pressure of 2 psi. From information on static resistance on air moving through soil, the typical resistance through 12 in of soil would be less than 10 in of water (0.4 psi). The MTDC blower design will use an electrical-driven, radial blade blower with an electronic speed controlled motor. This motor will be powered by the boiler generator. This generator is used to provide electrical power for the automatic boiler controls and water and fuel pumps. For the initial shakedown testing a leaf blower (Figure 6) was used to mix air with the steam. The advertised volume delivered by the unit was 350 CFM. The unit was installed and connected to the mixing chamber. The blade injector outlets were blocked off to determine what static pressure could be developed. A measurement of 10 in of water, (static head) was measured. Literature reviewed indicated that 6 in of water would be adequate in most soils for soil depths of 10 inches.

Blade

The blade that was designed for injecting steam underground is similar to an undercutter blade used for root wrenching or root pruning. A hollow base was added to the bottom of the blade (Figure 7). This created a steam chamber and openings were made at the back edge of this chamber below the blade to allow steam to be injected into the soil. The sides of the blade were constructed out of hollow rectangular tubing. The inside of these tubes were used as conduits for the steam from the blower/steam generator (Figure 8).



Figure 6—The leaf blower (foreground) was used for initial tests.



Figure 7—Rear edge of blade showing slots for steam ejection.



Figure 8—Inlet for the steam/air mixture delivered to blade.



Initial Test of the MTDC Steam Treatment Machine

During October 1995, weather did not permit testing at the Forest Service's Coeur d'Alene Nursery in Coeur d'Alene, ID. We briefly tried the machine at the Montana State Nursery in Missoula, MT. The ground was frozen in the morning, but thawed somewhat during the day. We operated the steam treatment machine in a bed where seedlings had been lifted earlier in the week. The soil was not level and the ground was not totally thawed.

In the short amount of time that we tested the machine at the MTDC shop and at the Montana State Nursery, our initial findings were:

- The vapor temperature in the duct downstream from the mixing chamber was about the same as at the blade outlets. A temperature gauge was inserted in the duct 3 ft from the mixing chamber. A temperature probe was inserted in the blade nozzle outlets and the temperatures compared. No measurements were taken to determine the volume of water vapor produced. The temperature of the vapor could be adjusted by opening up the steam throttle valve to its maximum opening and increasing the air flow until the desired temperature was reached.
- At lower temperatures with the blower that we had available, the steam valve had to be closed down when the blower was operating at maximum capacity. With a new blower design, the flow capacity should be high enough to provide adequate airflow; steam flow would be the limiting factor. This would ensure that the boiler would operate at maximum capacity.
- The gasoline-powered portable leaf blower that was used for the preliminary testing develops adequate pressure. It is

not known what volume of air was delivered at that pressure. This blower is not durable enough for field use but was adequate for initial testing.

- In the lifted seedling beds where we operated the machine, the blade had a tendency to push soil well in front of its leading edge. This may be caused by the blade having a blunt edge, by partially frozen ground, and by soil that was not consistent in texture.
- Some steam chimneying was noted around the ends of the steam injection blade and near the area where the temperature probe was located. If the soil had been uniformly tilled, this might not have been a problem. Some steam was lost where the machine's tires passed. If that continues to be a problem, some of the nozzles at the end of the injector blade can be closed off and the treatment width can be narrowed.
- The temperature probe (Figure 5), built to indicate temperatures at three levels in the soil profile, will need some redesign. During the brief test, it got packed with dirt that soon became mud. When this occurred all three thermocouples read the same temperature. The width of the probe also causes some problems. The soil has to be moved laterally and this may cause some soil to build up in front of the probe.
- Once heated, the soil holds the temperature for a long time. The tarp will trap steam and will allow the soil surface to be heated. During our brief test, the ambient and soil temperatures were about 40° lower than normally expected when the machine would be operated. Lower temperatures required more energy to bring the soil up to temperature.



Recommendations

As a possible solution to the soil building up in front of the blade's leading edge, a stainless steel sheet was added over the injector blade surface. This may not be a good long-term solution because the stainless steel surface may be worn away in a short period of time. The problem may disappear when the seedling bed is properly prepared. If the blunt edge of the blade (Figure 9) is the cause of the problem, it can be easily corrected.

The temperature probe will need to be modified. Because the steam/air mixture is being added to the soil in front of the temperature probe, the probe will always be operating in wet soil. A solution is not readily apparent at this time. Narrowing the probe will certainly help. It may be possible to more completely isolate the thermocouples more from each other.

If the area where the tires pass over the prepared seedling bed continues to present problems for steam loss, some of the end vapor ports of the injector blade may have to be closed off. This will prevent steam loss in the tire tracks, an area where the steam may escape more readily than in the middle of the injector blade. Loss of steam results in uneven heating of the treated soil.

Before making changes, I recommend more testing under better conditions, uniformly tilled soil that is not wet and cold.

Before rigorous testing is undertaken, a blower designed for continuous operation should be installed.

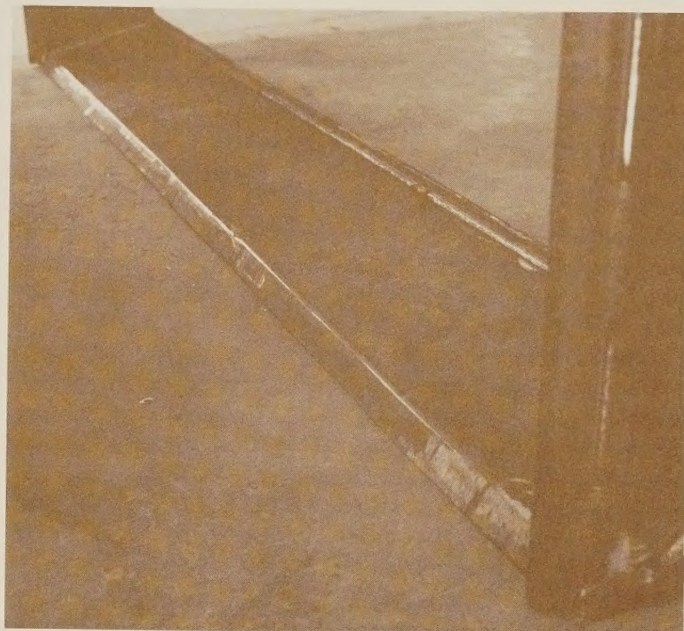


Figure 9—The blunt forward edge of the steam injector blade.

Future Considerations

If this design has merit after initial testing, the machine can be adapted to include a self-powered winch. A deadman (a tractor for instance) can be placed at the end of the seedbed and the winch attached to it. The machine can be

started up and operated without too much attention. When it reaches the end of the seedbed it could be moved to the adjacent bed and started again.



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Building 1, Fort Missoula
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Phone: (406) 329-3900
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For further technical information, contact Richard Karsky at the address above.

Library Card

Karsky, Dick. 1996. Steam treating soils: an alternative to methyl bromide fumigation. Tech. Rep. 9624-2818-MTDC. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. 10 p.

Summarizes previous use of steam treatment to sterilize soils in forest nursery seedbeds. Considers steam treatment as a possible alternative to fumigation with methyl bromide, a pesticide that will be banned from use in 2001. Reports preliminary results of limited tests of a prototype steam treatment machine designed by the Missoula Technology and Development Center.

Keywords: forest nurseries, seedbeds, pest control, soil sterilization.



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First Considerations

The first consideration in the design of a system is the selection of the hardware. This is a critical decision, as the hardware will determine the capabilities of the system. The selection of the hardware should be based on the requirements of the system, the budget, and the availability of the hardware. The hardware should be selected to meet the requirements of the system, and the budget should be considered in the selection process. The availability of the hardware should also be considered, as the hardware should be available when it is needed.

The second consideration is the selection of the software. This is also a critical decision, as the software will determine the capabilities of the system. The selection of the software should be based on the requirements of the system, the budget, and the availability of the software. The software should be selected to meet the requirements of the system, and the budget should be considered in the selection process. The availability of the software should also be considered, as the software should be available when it is needed.

Conclusion

The first consideration in the design of a system is the selection of the hardware. This is a critical decision, as the hardware will determine the capabilities of the system. The selection of the hardware should be based on the requirements of the system, the budget, and the availability of the hardware. The hardware should be selected to meet the requirements of the system, and the budget should be considered in the selection process. The availability of the hardware should also be considered, as the hardware should be available when it is needed.

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The third consideration is the selection of the personnel. This is also a critical decision, as the personnel will determine the capabilities of the system. The selection of the personnel should be based on the requirements of the system, the budget, and the availability of the personnel. The personnel should be selected to meet the requirements of the system, and the budget should be considered in the selection process. The availability of the personnel should also be considered, as the personnel should be available when it is needed.